Intravenous fluids in hospital: practical approaches

Medical practitioners of all grades need to realize the significance of appropriate prescription of intravenous fluids. Careless prescription of intravenous fluids may lead to dangerous complications (*Table 1*), potentially leading to delayed recovery, longer length of stay or, at worst, death. This article will initially discuss theoretical considerations and then use case studies as a revision exercise on prescription of intravenous fluids.

Physiology and pathophysiology

It is important to have an understanding of basic physiology and pathophysiology (Lobo et al, 2013). Fluid contained within the cells of the human body is termed 'intracellular fluid' (*Figure 1*). The extracellular space consists of the interstitial fluid and intravascular fluid. The interstitial fluid surrounds the cells and is separated from the intracellular space by the cell membrane.

Table 1. Consequences of intravenous fluid mismanagement
Hypokalaemia
Hyperkalaemia
Hyponatraemia
Hypernatraemia
Acute kidney injury
Fluid overload
From National Institute of Health and Clinical Excellence (2013)

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The intravascular space, separated from the interstitial space by the capillary endothelium, contains red cells, white cells and plasma (Lobo et al, 2013).

The cell membrane contains a sodium pump which ensures that sodium remains predominantly in the extracellular fluid. Conversely, potassium is predominantly in the intracellular compartment.

Historically, the Starling effect was used to explain transcapillary flow. Plasma has a high hydrostatic pressure forcing fluid out of the capillary membrane. The retention of large molecules in the plasma results in high plasma colloid oncotic pressure; this opposes the plasma hydrostatic pressure, potentially leading to absorption of fluid from the interstitial space into plasma (Woodcock and Woodcock, 2012).

Woodcock and Woodcock (2012) proposed a revision of Starling's theory. The capillary endothelium is lined, on the luminal side, by glycoproteins and proteoglycans termed the endothelial glycocalyx layer (Woodcock and Woodcock, 2012); this results in a semi-permeable membrane. Through a series of experiments, it was shown that absorption of fluid from the interstitial space to plasma does not occur; this is referred to as the 'no absorption rule'.

The composition of intravenous solutions

Knowledge of the composition of intravenous solutions is essential before prescribing intravenous fluids (*Table 2*). Frequently used intravenous solutions include: Plasma-Lyte 148, 0.9% sodium chloride (normal saline), 0.18% saline/4% glucose (dextrose saline), 5% glucose and Hartmann's solution. 5% glucose contains water and glucose. Following intravenous administration, the glucose is metabolized by the liver; the resulting free water is dispersed in both intracellular and extracellular space.

0.9% sodium chloride (otherwise known as 'normal saline') is a commonly used solution. In view of the semi-permeable nature of the capillary endothelium, 0.9% sodium chloride is distributed throughout the extracellular volume. As shown in *Table 2*, normal saline has a high concentration

Figure 1. Fluid spaces. Interstitial fluid and intravascular fluid constitute the extracellular fluid. For a 70 kg adult human, the total body water is 42 litres. This is divided into the extracellular fluid (14 litres) and the intracellular fluid (28 litres). The extracellular fluid is in turn divided into plasma (3 litres) and interstitial fluid (11 litres). From Guyton and Hall (2000).

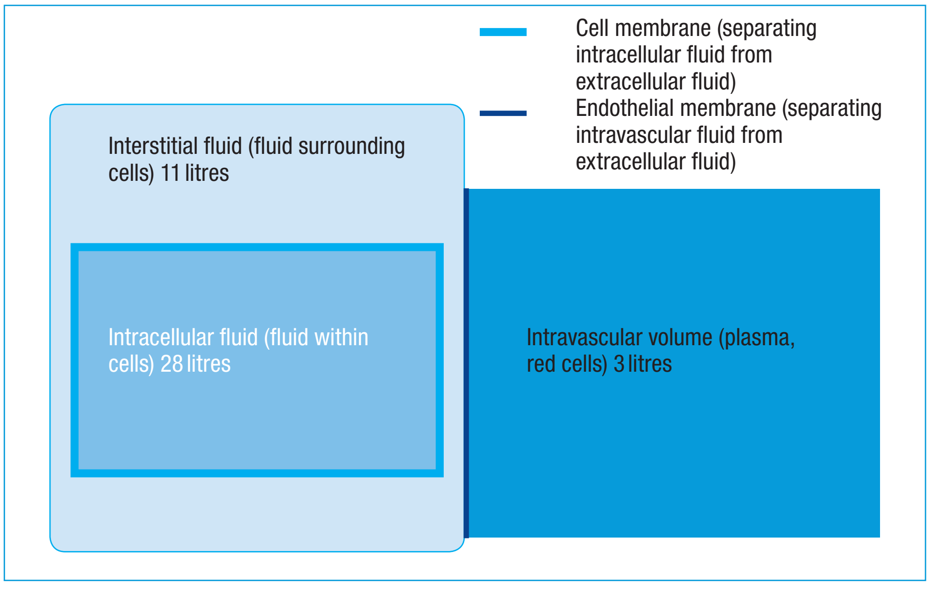

Table 2. Composition of commonly used intravenous solutions

Plasma-Lyte 148 (mmol/litre)	
Sodium	140
Chloride	98
Potassium	5
Magnesium	1.5
0.9% sodium chloride (normal saline) (mmol/litre)*	
Sodium	154
Chloride	154
Dextrose saline (0.18% saline/4% glucose) (mmol/litre)*	
Sodium	30
Chloride	30
Glucose	40 g/litre
5% glucose*	
Glucose	50 g/litre
Hartmann's solution (mmol/litre)	
Sodium	131
Chloride	111
Potassium	5
Bicarbonate	29

**Potassium may be added to these bags by the manufacturer. From National Institute of Health and Clinical Excellence (2013)*

of chloride. Balanced crystalloids such as Hartmann's solution and Plasma-Lyte contain a lower concentration of chloride than 0.9% sodium chloride and are closer in composition to plasma (*Table 2*). Moreover, other electrolytes present in balanced solutions include potassium and magnesium.

Dextrose saline (0.18% saline/4% dextrose) contains a lower concentration of sodium and chloride than 0.9% sodium chloride.

Concerns have been raised regarding the high concentration of chloride anions in 0.9% sodium chloride (*Table 2*). Studies have shown that use of normal saline is more likely to lead to hyperchloraemic acidosis and acute kidney injury compared to use of balanced crystalloids (Chowdhury et al, 2012; Yunos et al, 2012; Young et al, 2014). Moreover, the kidney is slow to excrete the high sodium load, potentially resulting in fluid overload. In contrast, a study in critically ill patients reported no difference in outcome of patients given 0.9% sodium chloride compared to those given balanced crystalloids (Young et al, 2015). Further studies are required to ascertain the safety and efficacy of normal saline compared to balanced crystalloids and the clinical significance of hyperchloraemic acidosis (Myburgh and Mythen, 2013; Young et al, 2015).

There are many colloids available: hydroxyethyl starches, succinylated gelatin and urea-linked gelatin. Colloids usually consist of a crystalloid solution with large molecular particles and proteins.

Are colloids superior to crystalloids?

There continues to be debate concerning the advantages of colloids *vs* crystalloids in resuscitation. In a Cochrane review, Perel et al (2013) concluded there were no advantages of colloids over crystalloids. In contrast, the CRISTAL study compared crystalloids and colloids in resuscitation of patients in a critical care environment (Annane et al, 2013), reporting a reduction in the secondary outcome of 90-day mortality in the colloid arm of the trial.

According to Starling's principles, colloids increase plasma oncotic pressure thereby increasing filtration of fluid from the interstitial space to the plasma (Woodcock and Woodcock, 2012). Theoretically this would confer an advantage of colloids over crystalloids; however, as stated above Starling's principles have been revised. The reason for a lack of benefit of colloids over crystalloids in some trials may be explained by the no absorption rule (Woodcock and Woodcock, 2012; Woodcock, 2017). Another factor to be taken into consideration is that transcapillary flow is close to zero if capillary pressures are low as a result of hypovolaemia (Woodcock and Woodcock, 2012; Woodcock, 2017). Therefore, for a hypovolaemic patient, both colloid and crystalloid will be contained within the intravascular space.

Colloids may cause anaphylaxis, acute kidney injury or bleeding diathesis (Frost, 2015). Of particular note, hydroxyethyl starches are no longer recommended in clinical use for patients with sepsis as the risk of renal failure (Myburgh et al, 2012) outweighs the benefit (Medicines and Healthcare products Regulation Agency, 2013). In view of increased expense, the lack of evidence of benefit and the potential for adverse events of colloids, balanced crystalloids are the preferred solution for resuscitation, compared to colloids and 0.9% sodium chloride (National Institute of Health and Clinical Excellence, 2013; Perel et al, 2013).

Case studies

Case 1

A 70-year-old man is admitted with community-acquired pneumonia. On examination, there are signs of hypovolaemia.

This patient is likely to have sepsis secondary to community-acquired pneumonia, requiring immediate assessment of airway, breathing and circulation. The patient needs high dose oxygen therapy, intravenous antibiotics and intravenous fluids.

Colloids, balanced crystalloids and 0.9% sodium chloride are used for resuscitation (National Institute of Health and Clinical Excellence, 2013). As stated above, a Cochrane review concluded that there were no advantages of colloids over crystalloids (Perel et al, 2013). Moreover, balanced crystalloids may confer an advantage over 0.9% sodium chloride in view of the lower concentration of chloride. The final choice of intravenous fluid for resuscitation is made by the attending practitioner.

Before prescribing intravenous fluids in any scenario, remember the 5Rs (*Table 3*) and assess the volaemic status of the patient (*Table 4*). In this case the patient is hypovolaemic. For the purpose of resuscitation, infuse a 500 ml bolus of a balanced crystalloid such as Hartmann's solution and then reassess the patient. If the patient is still hypovolaemic, further infusion of 250–500 ml of a crystalloid is required.

After 2 litres have been infused, practitioners should consider urgent assessment by the critical care team. If the patient remains hypovolaemic despite intravenous fluid resuscitation, then transfer to critical care may be appropriate for invasive monitoring and inotropic support.

Remember that dextrose saline and 5% glucose are not suitable for resuscitation as these solutions are dissipated throughout the fluid spaces.

In clinical practice, the signs of hypovolaemia as detailed in *Table 4* may be difficult to spot. For example, diabetics, the elderly or those on beta blockers may not develop tachycardia in response to hypovolaemia (Allison and Lobo, 2004). Moreover, younger patients may remain normotensive during the initial stages of hypovolaemic shock. Patients with chronic hypertension may be in a state of shock but have blood pressure readings within the normal range.

Fluid redistribution issues may cause difficulties. For example, a patient with nephrotic syndrome may have low serum albumin levels and peripheral oedema. Following a gastrointestinal haemorrhage, the patient may develop hypovolaemic shock, yet also remain oedematous, intravenous fluid resuscitation is required.

The patient improves. Blood pressure is 150/80 mmHg, pulse 80 beats/minute regular and capillary refill time less than 2 seconds. The patient is stepped down from the intensive care unit to the acute medical ward for further management.

Before prescribing intravenous fluids, reassess the patient. Examine the patient to determine volaemic status (*Table 4*), analyse the early warning scores, observation chart and fluid balance chart, and ensure that the urea and electrolytes from that same day have been seen. The patient is now euvolaemic and needs intravenous fluids prescribing for the purpose of maintenance.

Assuming this person weighs 70 kg, the daily requirements of water is 2100 ml/day and of sodium, potassium and chloride is 70 mmol (*Table 5*). If 2.1 litres of dextrose saline is prescribed in a 24-hour period, this will provide approximately 60 mmol of sodium, which is close to, but does not quite reach, the daily requirement of 70 mmol. The main issue with dextrose saline is that there is a risk of hyponatraemia as sodium content falls slightly short of daily requirements. Therefore, urea and electrolytes need to be monitored and clinicians should be careful not to prescribe excess dextrose saline.

When prescribing intravenous fluid for maintenance, ensure sufficient potassium supplementation is prescribed. Potassium supplementation is required even if the serum potassium level is within the normal range. Failure to prescribe intravenous fluids with potassium supplementation may place the patient at risk of hypokalaemia. If a patient's potassium level is already raised, or increasing as a result of developing renal failure, do not give potassium in maintenance fluids. Solutions containing potassium chloride are prepared by the manufacturers.

As shown in *Table 5*, patients require glucose for the purpose of maintenance in order to prevent starvation ketosis; 5% glucose and dextrose saline contain sufficient glucose for this purpose.

Practitioners need to be cautious in prescribing excess 0.9% sodium chloride for maintenance. 1 litre of 0.9% sodium chloride contains 154 mmol of sodium and 154 mmol of chloride. If 3 litres of normal saline per day is given injudiciously for maintenance,

Table 3. The 5 Rs

Routine maintenance	Intravenous fluid is prescribed for maintenance if the patient is unable to take fluids enterally. The patient is euvolaemic and does not have fluid losses above insensible loss
Replacement	Intravenous fluid is prescribed to replace excessive fluid losses, for example as a result of diarrhoea, gastric aspirate, surgical drains or ileostomy
Resuscitation	Intravenous fluid is required if the patient is hypovolaemic, for example as a result of dehydration or sepsis
Reassessment	Once intravenous fluids have been administered, it is necessary to reassess the patient regularly
Redistribution	Such patients have complex redistribution of fluid issues

Table 4. Assessing volaemic status

Hypervolaemia	Raised jugular venous pressure
	Presence of third heart sound
	Peripheral oedema (sacral oedema and ankle oedema)
	Pulmonary oedema (basal crackles, wheeze)
Hypovolaemia	Capillary refill time greater than 2 seconds
	Hypotension
	Postural hypotension
	Tachycardia
	Reduced skin turgor (unreliable sign in the elderly)
	Dry mucous membranes

Table 5. Maintenance requirements for fluid and electrolytes per day

Maintenance requirements for fluid: 25–30 ml/kg/day

Maintenance requirements for potassium, sodium and chloride: approximately 1 mmol/kg/day

Maintenance requirements for glucose: approximately 50–100 g/day

Body weight (kg)	Fluid requirements (ml/day)	Rate (ml/hour)
35–44	1200	50
45–54	1500	65
55–64	1800	75
65–74	2100	85
>74	2400	100 (max)

The National Institute of Health and Clinical Excellence (2013) guidelines state that in elderly frail patients the requirement may be closer to 20–25 ml/kg/day. Adapted from Fluid Prescription Working Group (2014) this will administer 462 mmol of sodium and chloride, grossly superseding daily requirements.

If a balanced crystalloid or 0.9% sodium chloride is prescribed for maintenance, then the patient has already received sufficient sodium for that day. To avoid administering any further sodium for that day, consider use of 5% glucose, but avoid excess 5% glucose; hyponatraemia may ensue because of the dilutional effect.

In practice, for the purpose of maintenance, consider use of 0.18% saline/4% glucose (dextrose saline) with potassium 40 mmol at the correct rate according to weight (*Table 5*). This will give approximately the correct amounts of water, sodium, potassium and glucose.

Case 2

A 77-year-old man returns from theatre, having undergone a right hemicolectomy earlier that morning. In theatre, he had 3 litres of 0.9% sodium chloride. On examination the patient is euvolaemic. His pulse is 80 beats/minute regular, blood pressure 120/80 mmHg and capillary refill time less than 2 seconds. The nurse is concerned as over the last 3 hours his urine output has been:

- 1–2 pm 20 ml
- 2–3 pm 10 ml
- 3–4 pm 15 ml

Immediately following surgery or during acute illness, antidiuretic hormone is released from the posterior pituitary, causing the kidney to retain water. This is a physiological response to acute illness (Powell-Tuck et al, 2011). If there are no signs of hypovolaemia then there is no need to increase the rate of infusion of intravenous fluids. In this scenario, it is conceivable that normal saline may have induced renal vasoconstriction, contributing to oliguria. Further overzealous infusion of fluids may cause fluid overload, delaying recovery.

If the patient does display signs of hypovolaemia in the postoperative period then careful assessment and fluid resuscitation is required – a fluid challenge of 500 ml of balanced crystalloid may be administered, followed by monitoring of the response.

Case 3

An 88-year-old woman suffers from heart failure, chronic kidney disease and pressure ulcers. She is admitted with a fall. She was found within minutes by her daughter. On examination she has:

- Severe oedema of both legs up to mid thigh
- A few bilateral basal crackles. Jugular venous pressure not confidently seen
- Pulse 80 beats/minute regular, blood pressure 130/60 mmHg
- The nurses report that she is drinking and eating with no further vomiting
- Sodium 120 mmol/litre, potassium 4.4 mmol/litre, urea 12 mmol/litre, creatinine 120 mmol/litre, albumin 15g/litre.

This is an example of fluid redistribution issues. The patient has heart failure, leading to development of peripheral oedema. Moreover, the low serum albumin level reduces plasma oncotic pressure, further increasing peripheral oedema. The hyponatraemia may be a result of a dilutional effect from fluid overload or sodium loss from diuretic administration.

Complex redistribution issues are prevalent in patients with sepsis, cardiac failure, renal impairment and malnutrition, resulting in an oedematous state. These patients require senior input into their fluid management.

Case 4

A 78-year-old man had a stroke 1 week ago; 2 days ago, he developed profuse diarrhoea, passing large volumes of stool five times a day. The patient is euvolaemic. Reviewing his fluid balance chart shows that yesterday he took only 200 ml orally.

This patient requires intravenous fluids for the purpose of replacement of losses, in this case as a result of diarrhoea. A balanced crystalloid may be suitable to replace diarrhoeal loses. In addition, the patient may require intravenous maintenance fluids as oral intake is low.

Table 6. Examples of excessive losses of fluid
Upper gastrointestinal tract: vomiting, gastric aspirate
Lower gastrointestinal losses: diarrhoea, ileostomy, colostomy
Surgical drains
High insensible losses: fever
Burns

TOP TIPS

- Be clear in your mind as to the reason you are prescribing intravenous fluids. For example, intravenous fluids may be required for maintenance, replacement or resuscitation.
- Be mindful to avoid serious complications of intravenous fluids. For example, 0.9% sodium chloride may lead to fluid overload if administered in excess.
- Plan ahead! Ensure you have requested daily urea and electrolytes for patients on intravenous fluids. If possible, attempt to prescribe intravenous fluids during working hours to avoid inundating the on-call staff.

Excessive loss of fluid may occur in many conditions (*Table 6*), for example after major colonic surgery, fluid losses may arise from ileus leading to high gastric aspirates, surgical drains or high output ileostomy. On the ward rounds, calculate the fluid losses and prescribe intravenous fluids for replacement accordingly. This patient is taking 200 ml orally. This amount should be subtracted from the total volume of intravenous fluids the doctor wishes to prescribe.

The choice of intravenous fluid for the purpose of replacement depends on the fluid lost. For example, upper gastrointestinal fluid has a high concentration of chloride ions, therefore 0.9% sodium chloride may be used, making use of the high concentration of chloride.

Case 5

A 78-year-old man is admitted with a fall. He has a history of hypertension, atrial fibrillation, heart failure and ischaemic heart disease. His drug history is furosemide, ramipril, amlodipine and metoprolol.

On examination:

- His blood pressure is 90/60 mmHg and his heart rate 110 beats/minute irregularly irregular
- The patient has a dry mouth and reduced skin turgor
- His chest was clear
- The jugular venous pressure cannot be visualized and there is no peripheral oedema
- Sodium 130 mmol/litre, potassium 4 mmol/litre, urea 11 mmol/litre, creatinine 140 mmol/litre.

KEY POINTS

- Careless prescription of intravenous fluids may lead to dangerous complications, e.g. fluid overload or dehydration.
- Before prescribing intravenous fluids, assess the patient's volaemic status; is the patient hypervolaemic, euvolaemic or hypovolaemic?
- Know the composition of intravenous solutions. For example, 0.9% sodium chloride contains a high concentration of chloride and sodium ions.
- For resuscitation, consider infusion of a bolus of 500 ml of a balanced crystalloid. 0.9% sodium chloride or colloids are alternatives. Then reassess the patient, and infuse a further bolus of 250–500 ml. Once you have infused 2000 ml, get help from a senior colleague.
- For the purpose of maintenance, the volume of intravenous fluids is dependent on the patient's weight. Potassium supplementation may be required even if potassium levels are in the normal range. Dextrose saline is an appropriate solution for the purpose of maintenance.
- Reassess the patient. Review the fluid balance charts, the early warning scores, observation chart and urea and electrolytes from that day.
- Excessive fluid loss may be as a result of for example, gastric aspirate, diarrhoea or surgical drains. Replacement of excess losses of fluid is required.

To the uninitiated, this patient may have signs of hypovolaemia. However, dry mouth and reduced skin turgor are not reliable signs of dehydration (McGee et al, 1999) and are not infrequently seen in the elderly population. This patient may be hypotensive as a result of diuretics, antihypertensive medication and impaired left ventricular function. The raised urea level may be a result of long-standing chronic kidney disease rather than hypovolaemia.

A common error is to assume that this patient is hypovolaemic and infuse copious volumes of intravenous fluids, leading to fluid retention. Such cases are complex. A fluid challenge of 500 ml bolus of a balanced crystalloid followed by reassessment of the patient may be appropriate initially; the patient requires chest X-ray, electrocardiogram and echocardiography to assess his cardiac function.

Intravenous fluid management in practice

Think before prescribing intravenous fluids. When reviewing a patient on ward round, or ward review, do not forget to take a history, examine the patient, analyse the fluid balance charts, take into account the early warning scores and obtain the results of the recent urea and electrolytes (National Institute of Health and Clinical Excellence, 2013).

Look at the input chart. The patient may be starting to drink or may be receiving fluids by means of enteral feeding tubes. Fluids may be required in order to administer intravenous medication such as antibiotics, inotropes or antiepileptic drugs. Fluid intake from other sources needs to be taken into account before prescribing intravenous fluids.

As far as possible, prescribe intravenous fluids for patients during the daytime. It is difficult for busy on-call staff to prescribe intravenous fluids for patients not known to them. Fluid-related errors should be reported through the local safeguarding system so that practitioners may reflect and learn.

Conclusions

Medical practitioners of all grades need to realize that a comprehensive assessment followed by appropriate prescription of intravenous fluids will improve outcome of their patients. Remember to be clear on the indication for prescription of intravenous fluids and follow the principles of the 5Rs (*Table 3*). **BJHM**

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