3

Which fluid and why?

Key points

- Blood products, colloids and crystalloids are the three main fluid types used in veterinary practice
- Blood transfusion requires a suitable donor and checks for compatibility
- The aim is to replace 'like with like' by choosing appropriate fluids for the condition and the expected or actual water/electrolyte losses occurring in the patient
- Potassium levels should ideally be monitored and any disturbances treated as necessary

The aim of fluid therapy is to replace losses and maintain fluid and electrolyte balance in the body, thus allowing for normal cell and organ function. A number of commercially available fluids are suitable for this purpose, and will be discussed in this chapter.

To understand where a fluid is going after it leaves the intravenous catheter, a basic knowledge of fluid distribution in the body is required (see Ch. 1). It is important to remember that the fluid compartments in the body exchange fluid to compensate for losses: thus fluid lost initially from one compartment inevitably results in a loss from all compartments.

Classification of fluids

The fluids used in intravenous fluid therapy are generally classified into the following three groups:

1. Whole blood and blood products
2. Colloids
3. Crystalloids.

Whole blood and blood products

Whole blood is used in cases of:

- Severe haemorrhage
- Severe anemia

- Specific problems (e.g. Von Willebrand's disease) where it is necessary to provide platelets or clotting factors.

Blood collection

Blood is collected from the donor animal using a blood collection bag containing an anticoagulant: citrate phosphate dextrose (CPD) is commonly used. The blood donor must be clinically healthy and have a normal packed cell volume. Dogs should weigh a minimum of 25 kg; cats should not be obese and should test FeLV, FIV and FIA negative.

It is a legal requirement in the UK that blood may only be taken from an animal for a specific patient: blood cannot be taken from a donor and then stored for use on any patient in the future. Some large establishments keep donor dogs on site but this is impractical in most practice situations due to economic and space restrictions. The donor is often a pet belonging to a member of staff or a willing client and can be called upon when needed. If blood is taken from a donor animal for a specific patient but is then *not* used (e.g. if the animal dies) or if not all the donor blood is used, surplus blood can be stored. Whole blood can be stored between 1–6°C for up to three weeks.

Blood is usually collected from dogs using a standard blood collection bag (Fig. 3.1). One unit (400 mL) can be collected safely from the donor. If the primary purpose of the transfusion is administration of red cells, sight hounds (e.g. Greyhounds) that have a naturally high packed cell volume are preferred as donors. The donor dog does not usually require sedation. Blood is collected from the jugular vein and local anaesthetic may be infiltrated into the skin before venepuncture. During collection, the dog is kept in a comfortable position – sitting, standing or sternal recumbency – and the vein is raised. The collection needle, which is pre-attached to the blood collection bag by the manufacturer, is placed into the vein and held firmly during collection. The bag is held below the donor and agitated gently during collection to mix the blood with the anticoagulant. Collection is continued until the bag is full: weighing the bag or identifying when it is turgid with blood assesses fullness (Fig. 3.2). After the needle has been removed from the vein, a firm neck bandage is kept in place for two hours to avoid the formation of a haematoma.

Blood collection from cats is also from the jugular vein and is collected into a large syringe. Donor cats may require sedation although this should be avoided unless absolutely necessary. Up to 50 mL can be collected from a large healthy cat. 1 mL of anticoagulant is drawn into the syringe for every 9 mL of blood to be collected. The cat is restrained in a sitting position or upside down in the handler's lap. The blood is collected with a large (20 G) needle using good venepuncture technique.

Figure 3.1 Blood collection bag before use. It contains anticoagulant and has a needle attached.

Blood grouping

In dogs, there are eight isoantibody (blood grouping) systems, given the numbers 1–8. The only one that has any real clinical importance is DEA (dog erythrocyte antigen) 1. Whilst all of the dog blood groups can potentially stimulate transfusion reactions, DEA 1 will cause the most severe reaction. Dogs can be blood typed and dogs that are DEA 1 positive should be avoided as donors.

In cats, the blood groups are much simpler. There are basically three groups: A, B and AB. Cats should be cross-matched or blood typed before any transfusion, since there is a significant risk of a clinically important transfusion reaction.

Although transfusion reactions rarely occur in dogs that have not been transfused before, the risk of a reaction occurring increases with each transfusion that is given. This means that, ideally, donor and recipient dogs should be blood typed and dogs or cats that have been transfused previously should be cross-matched before subsequent transfusions. Blood typing is more accurate than cross-matching since blood typing

Figure 3.2 Full blood collection bag. The bag appears turgid and can be weighed to assess fullness.

looks for particular antigens on the surface of the red blood cell. Commercial blood testing kits are available for use in general veterinary practice. Where these kits are not available, cross-matching the donor and recipient blood helps to avoid transfusion reactions.

Cross-matching helps to avoid any incompatibility reactions. It involves taking a blood sample from the donor and recipient and testing to determine cross-reactions between plasma and red blood cells. This predicts the likelihood of an immediate transfusion reaction happening – it does not predict future antibody reactions.

Preferably, a full cross-match should be performed. An EDTA blood sample from the donor and the recipient is centrifuged at 3000 rpm for 10 minutes and the supernatant removed. The erythrocytes are resuspended in saline and this is centrifuged again at 3000 rpm for 10 minutes. The supernatant is removed and the erythrocytes are resuspended again in saline to make a 3–5% solution. A *major cross-match* will assess the effect that recipient serum antibodies will have on donor cells. It is performed by mixing two drops of donor red cell suspension with one or two drops of recipient plasma in a test tube. A positive result is

Box 3.1 Simple blood compatibility test

Cross-matching can be performed in general veterinary practice. A simple compatibility test can be performed on blood:

- Place two drops of donor blood in EDTA into 1 mL of saline and add two drops of patient serum.
- Centrifuge at a low speed for 15–30 seconds.
- Flick the tube to resuspend.
- If signs of agglutination are present this suggests incompatibility.
- This test does not test for haemolysis.

indicated by haemolysis or agglutination. A *minor cross-match* will assess the effect that donor serum will have on recipient cells. It is performed by mixing two drops of recipient red cell suspension with one or two drops of donor plasma in a test tube. Incubate the test tube at 37°C for 60 minutes. Haemolysis or agglutination indicates a positive result.

Administration of blood

Blood is administered to the recipient through a blood giving set with filter (Fig. 3.3). The purpose of the filter is to remove any clots and prevent them from entering the recipient's circulation. The flow rate of the blood administration set must be noted in calculating the rate of infusion of blood. Blood should be carefully warmed to 37°C prior to administration – overheating will result in agglutination and protein breakdown.

Blood is administered at an initial rate of 0.25 mL/kg/hour for the first 15 minutes. Constant monitoring of the recipient during this time enables observation of any potential transfusion reaction. The rate is then increased to 20 mL/kg/hour. The total volume of blood is administered over 2–4 hours.

Giving an animal blood does involve some practical problems. If clotting factors and platelets are to be supplied, the blood must be given immediately it is taken from the donor: it cannot be stored. Incompatibility reactions are most likely in the first hour following transfusion and the patient must be monitored closely. There are numerous signs that indicate a transfusion reaction (Box 3.2) and these can vary from very mild to serious life-threatening situations. If the patient is showing any abnormal clinical signs the veterinary surgeon should be

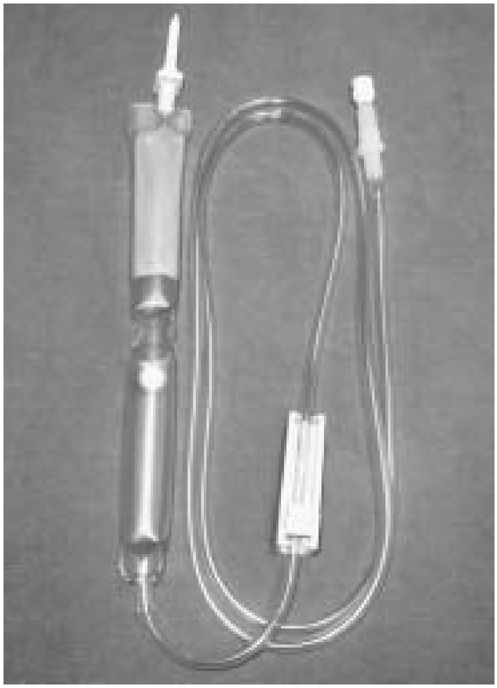

Figure 3.3 A blood giving set incorporating a filter to remove clots.

Box 3.2 Clinical signs associated with blood transfusion reactions

- Urticaria
- Hypersalivation
- Muscle tremors
- Tachycardia
- Vomiting/nausea
- Restlessness
- Jaundice
- Dyspnoea
- Haemoglobinuria
- Pyrexia
- Facial oedema
- Tachypnoea
- Convulsions

informed immediately and the transfusion stopped. The usual treatment of a blood transfusion reaction is to administer crystalloid fluids, antihistamines, antibiotics and corticosteroids.

Oxyglobin™

Oxyglobin™ (Fig. 3.4) is a plasma volume expander containing haemoglobin that improves oxygen delivery by increasing the oxygen content of the blood and expanding vascular volume. It is currently only licensed for use in dogs and is indicated in cases of severe anemia. The main advantages in using Oxyglobin™ rather than whole blood is that no blood typing or cross-matching is necessary since a transfusion reaction is unlikely. There is no need for a donor animal – thus saving time. However the cost of Oxyglobin™ currently prohibits regular use of the product.

Side effects can be seen. A transient red-brown discolouration of patient's urine, a yellow-red discolouration of skin, mucous membranes

Figure 3.4 Oxyglobin™ – a plasma expander containing haemoglobin – is an alternative to blood tranfusion.

and sclera and yellow/orange/red spots on skin may be noted. These minor side effects usually last for 3–5 days.

Oxyglobin™ is warmed to 37°C prior to use and is administered via a standard giving set and intravenous catheter. It must not be administered in conjunction with any other fluids. The recommended dose is 30 mL/kg intravenously at a rate of up to 10 mL/kg/hour.

Colloids

Colloids are a group of fluids containing large molecules designed to remain in the intravenous space longer than crystalloid fluids. This means that colloids are able to expand and maintain the vascular volume more effectively. Their osmotic potential is so great that colloids draw fluid out of the interstitial and intracellular spaces into the plasma, hence colloids are commonly termed ***plasma expanders***.

Colloids are used in cases of shock where cardiovascular function needs to be improved rapidly:

- Haemorrhage
- Shock
- Severe dehydration.

Following haemorrhage, colloids are sometimes administered rather than blood because obtaining a blood donor is not always easy and they avoid the possibility of a blood transfusion reaction if cross-matching is not possible or practical.

Dextrans

These are artificial colloids with a high molecular weight. They are not available on the veterinary market in the UK but are available in the USA.

Gelatins

Gelatins are straw coloured, isotonic colloid solutions. The two trade names in common use in the UK are Haemaccel™ and Gelofusin™. Gelatins should be stored at room temperature. They are administered through a standard fluid administration set and intravenous catheter. The patient does not require cross-matching before administration and gelatins must not be administered with whole blood.

Plasma

Plasma is also considered in this fluid category. Whole blood can be separated, e.g. by centrifugation, into plasma and packed red cells.

However, facilities for this are rarely available in general veterinary practice. When possible, it does allow the patient to receive specific treatment with plasma proteins, whilst minimising the risk of a cross-reaction. See also Oxyglobin™ above.

Crystalloids

Crystalloids are a group of sodium-based electrolyte fluids. They enter the extracellular fluid (ECF) and from there equilibriate with other fluid compartments in the body to restore fluid balance. The most commonly used crystalloids are similar to plasma water in composition. In patients where renal function is normal, crystalloids will be excreted in the urine.

Hartmann's (lactated Ringer's) solution

Hartmann's contains electrolytes in very similar concentrations to those in the extracellular fluid (ECF). Sodium (Na^+), potassium (K^+), calcium (Ca^{++}), chloride (Cl^-) and lactate are present.

Hartmann's is indicated in many cases of fluid and electrolyte losses. The lactate present is metabolised to bicarbonate, and this is used in the body to overcome situations of metabolic acidosis, which occur in many clinical conditions.

0.9% sodium chloride (saline)

This solution contains sodium (Na^+) and chloride (Cl^-), but no potassium (K^+). 0.9% sodium chloride is indicated in fluid and electrolyte losses, particularly when plasma potassium levels are increased due to underlying disease and additional administration of potassium must be avoided during fluid therapy.

5% dextrose

5% dextrose, also referred to as 5% glucose, is basically water with a small amount (50 mg/mL) of glucose added in order to make it isotonic, thus enabling it to be administered intravenously. This solution contains no electrolytes so provides the body with water and a very small amount of glucose. 5% dextrose is indicated in situations of primary water loss, where the animal is unable to take in oral fluids, and in cases of hypoglycaemia. The amount of glucose present is too little to make a significant contribution to the energy intake of the animal.

0.18% sodium chloride and 4% glucose (glucose-saline)

Glucose-saline is mainly water but also has a small amount of sodium and chloride to replace daily urinary losses in the normal animal. It is used in cases of primary water loss and occasionally as a maintenance fluid, although in the latter case potassium should be added to the drip bag.

Ringer's solution

Ringer's solution contains mainly sodium, chloride and some potassium. It is indicated in water and electrolyte loss when there is also some potassium deficit. It is mainly used in cases of pyometra when severe vomiting is present. Vomiting leads to substantial losses of hydrogen and chloride which in turn produces an excess of sodium. The kidneys try to compensate for the sodium excess, which can give rise to hypokalaemia.

Darrow's solution

This solution contains sodium, chloride, and potassium in higher concentrations than Ringer's or Hartmann's. Darrow's solution is mainly indicated in cases of metabolic acidosis with potassium deficiency, e.g. persistent diarrhoea.

Hypertonic saline (7.8% or 9% sodium chloride)

Hypertonic saline is under-used in small animal intravenous fluid therapy, but is more widely accepted in large animal fluid therapy (see Ch. 8). When this type of sodium chloride is administered intravenously, its high osmotic potential causes fluid from the intracellular space to move into the vascular space. This causes a sudden rapid increase in circulating volume that is needed in cases of severe hypovolaemia. Hypertonic saline is therefore indicated in situations such as: gastric dilation and

Table 3.1 Replacement fluid constituents for commonly used products

Fluid	Na^+ (mmol/L)	Cl^- (mmol/L)	K^+ (mmol/L)	Ca^{++} (mmol/L)	Others
0.9% sodium chloride	154	154	–	–	–
Hartmann's solution	131	111	5	2	Lactate
Ringer's solution	147	156	4	2.5	–
5% dextrose	–	–	–	–	5% dextrose
0.18% NaCl & 4% dextrose	30	30	–	–	4% dextrose
Darrow's solution	121	103	35	–	Lactate
Haemaccel	145	150	5	3	Gelatins
Hypertonic saline	855	855	–	–	–
Normal plasma	145	100	5	–	Lactate

volvulus (GDV), equine colic, severe haemorrhage. Typically, a 7.8% solution of hypertonic saline is administered intravenously at a rate of 4–5 mL/kg.

Potassium supplementation

Potassium may be added to a crystalloid fluid in cases of hypokalaemia. However, potassium supplementation is not often performed in general practice since it should only be carried out when blood potassium levels can be measured, and many practices are unable to do this using in-house blood analysers.

Hypokalaemia becomes important when plasma levels fall below 3.5 mmol/L. Patient potassium levels should be measured and potassium supplementation administered accordingly in 'at risk' patients (Box 3.3). Recommended supplementation doses are shown in Table 3.2. Potassium supplementation doses of 0.5 mmol/L/kg/hour should not be exceeded due to risks of hyperkalaemia and cardiotoxicity.

If potassium is added to a bag of crystalloid fluid it must be mixed thoroughly by inverting the bag of fluid several times. The fluid bag must then be labelled to indicate that potassium has been added.

Box 3.3 Common causes and signs of hypokalaemia

Causes	**Signs**
Vomiting	Weakness
Diarrhoea	Lethargy
Renal disease	Anorexia
Anorexia	Ileus
Diet low in potassium	
Aggressive diuretic therapy	

Table 3.2 Potassium replacement doses in hypokalaemia

Serum potassium (mmol/L)	Potassium chloride added to fluids (mmol/L)
3.6–5.0	20
3.1–3.5	30
2.6–3.0	40
2.1–2.5	60
<2.0	80

Figure 3.5 It is important that potassium and other additives are noted clearly on infusion bags and in the patient's clinical record.

Clinical situations requiring fluid therapy

When presented with a clinical case, a decision must be made as to which fluid to use to treat the animal's condition. Generally we try to 'replace like with like'. This simply means that where blood is lost, replace the deficit with blood; where water is lost, replace with water; and where water and electrolytes are lost, replace water and electrolytes.

Blood loss

Blood loss reduces the circulating volume and perfusion, and therefore reduces the oxygen carrying capacity of blood. A low packed cell volume (PCV) indicates this. In severe blood loss oxygenation of the tissues is significantly compromised. Generally, if the PCV falls below 20% then a blood transfusion is necessary. During surgery, if the patient loses more than 18 mL/kg of blood then a blood transfusion is also indicated. Anemia and bleeding disorders can be an indication for blood to

Table 3.3 Indications for different replacement fluids

Fluid	Indications for use
0.9% sodium chloride	Alkalosis, vomiting, urinary obstruction, hepatic disease
Hartmann's solution	Diarrhoea, acidosis, endocrine disease
Ringer's solution	Pyometra, severe vomiting
5% dextrose	Primary water loss, hypoglycaemia
0.18% NaCl & 4% dextrose	Maintenance requirements, hypoglycaemia
Darrow's solution	Severe diarrhoea
Haemaccel	Blood loss
Hypertonic saline	Severe haemorrhage, hypovolaemia
Blood	Haemorrhage

be given. Many animals with chronic anemia, however, will tolerate a low PCV without clinical signs.

For severe blood loss, using the 'like for like' rule, blood is the first choice of replacement fluid. If blood is unavailable, the second fluid choice is a colloid; this will expand the vascular space. If there is no colloid, then a crystalloid can be given. Hartmann's is most similar in composition to plasma. Blood volume needs to be replaced and whilst this is being carried out it is necessary to monitor PCV to ensure this remains at a sufficient level for oxygen requirements.

A packed cell volume of 20–25% is considered a minimum level in acutely affected animals (chronic cases will tolerate lower PCVs).

Primary water loss

This is loss of water with little or no loss of electrolytes. In this situation, water only needs to be replaced. Common conditions causing this include fractured jaw, panting, neglect by owners and unconsciousness. Crystalloids are the fluids of choice: 5% dextrose or 0.18% sodium chloride and 4% glucose are used.

Loss of water and electrolytes

This occurs as a result of conditions producing clinical signs such as vomiting and diarrhoea. A crystalloid containing both water and electrolytes must be used to replace the deficit. An important consideration in deciding which crystalloid to use is whether potassium is being lost or is accumulating in the body. This ion is important for normal metabolism and plasma potassium concentration must remain stable within narrow limits in order for body cells to function normally.

Table 3.4 Common clinical conditions and suggested fluids

Condition and consequences	Need to supply	Fluid of choice	Comments
Diarrhoea • Loss of water and electrolytes • Loss of K^+ through GI tract • Metabolic acidosis	• Water and electrolytes • K^+ • Bicarbonate/lactate	Hartmann's solution	
Severe blood loss • e.g. during surgery	• Red blood cells and plasma	Whole blood	
Vomiting • Loss of water and electrolytes • Metabolic alkalosis	• Water and electrolytes	0.9% NaCl	If vomiting progresses, K^+ will be lost and must be replaced: Hartmann's or Ringer's can be given
Pyometra A complicated situation with many disease processes present • Loss of K^+ since animal may be vomiting, anorexic; patient often has a vaginal discharge • If patient is shocked, will become acidotic • If patient is vomiting profusely, will become alkalotic • Patients with pyometra are *usually* considered acidotic	• Water and electrolytes • K^+ • Correct acidosis	Hartmann's solution	
Anorexia • Primary water loss	• Water	0.18% NaCl + 4% dextrose	If prolonged, anorexia leads to loss of K^+ so Hartmann's is indicated
Urinary tract obstruction (cats) • Hyperkalaemia	• Water and electrolytes	0.9% NaCl	Build up of K^+ is more life threatening than metabolic acidosis, so ensure fluids administered do not contain K^+

In the healthy animal, potassium is lost slowly in urine and is obtained through food. Any disease affecting either of these two functions will alter potassium levels in the body, e.g. excessive losses in urine lead to potassium depletion; urinary tract obstruction leads to an accumulation of potassium since it is not excreted; starved animals are unable to obtain potassium in food, so depletion occurs.

> In conditions of potential potassium depletion, a crystalloid containing potassium and other electrolytes to replace losses is required. In conditions of potential potassium accumulation, then crystalloids containing potassium must be avoided.

The final consideration when selecting a fluid is any change in the animal's acid–base balance (see also Ch. 4). In situations of metabolic acidosis, bicarbonate ions are needed – this is achieved by supplying lactate (contained in Hartmann's solution), which is metabolised by the body into bicarbonate. Sodium bicarbonate solution is also available to add to crystalloid fluids. In situations of metabolic alkalosis, bicarbonate should not be given to the animal and crystalloid fluids containing lactate should be avoided.

Hartmann's solution and whole blood must not be administered via the same catheter at the same time because the calcium in Hartmann's solution causes blood to clot. Administration to the same patient at the same time using separate i.v. catheters is however permissible, and this is also true for other calcium-containing fluid therapy products.

Table 3.4 outlines the fluid therapy requirements for some of the commonest conditions encountered in general veterinary practice.